Nightshade Velocimetry Needs

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5/17/2018

NNSA
National Nuclear Security Administration

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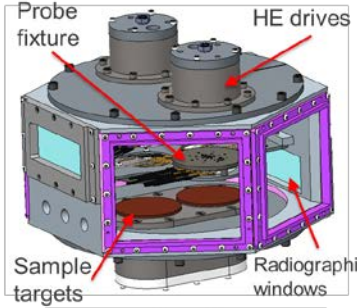
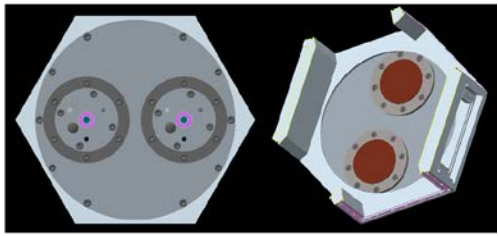
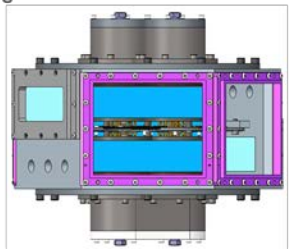
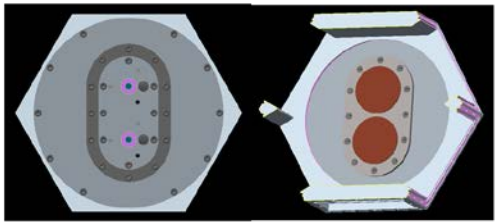
Nightshade

- Series of double-shock experiments at U1a in 2019 and 2020
- Designed to study ejecta produced in double-shock experiments
- 3 shots, each with six independent targets + double-shock charges









Diagnostics for Nightshade

- Lithium niobate pins
- Asay foils (measured with mPDV)
- Soft X-ray radiography
- Cygnus radiography
- PDV ← The focus of this talk
- Broadband laser ranging (BLR)
- Time of arrival diagnostic (TOAD)
- MWE/Mie
- Surface reflectance spectrometry

Goals for PDV on Nightshade

- **Required:**
  - Timing of first shock, second shock
  - Velocities of the surface between the shocks
  - Give complementary information to pins and Asay foils
- **Desired:**
  - Velocity of the surface after second shock
  - Quantitatively measure ejecta features seen in the PDV traces
  - Observe traces until probe impact

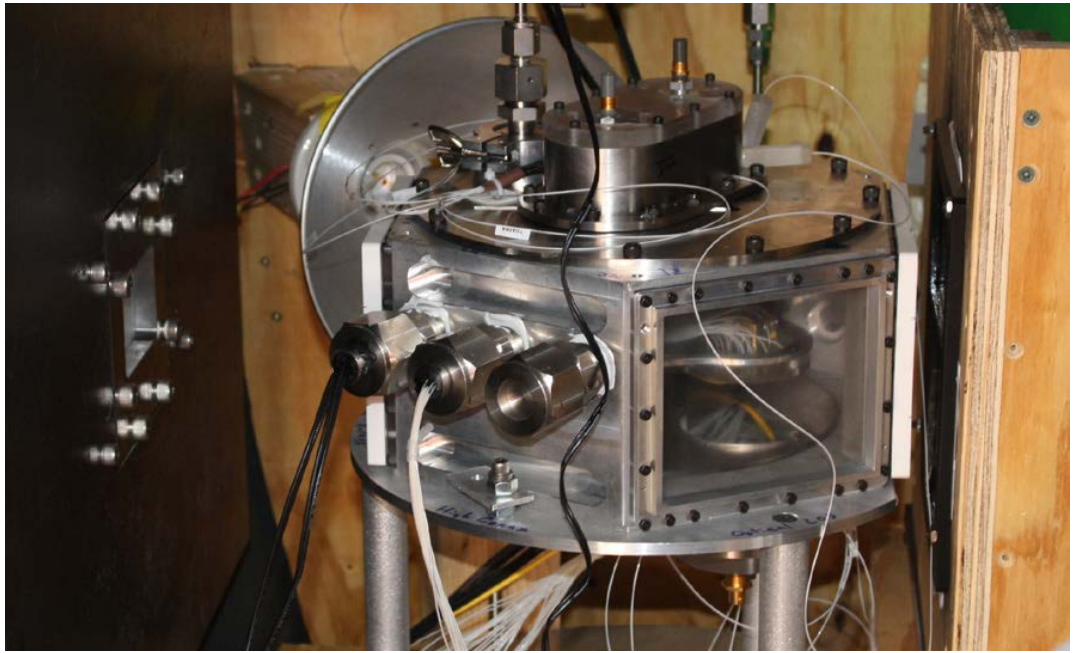
Issues for PDV on Nightshade

- Seeing through ejecta is difficult
- Is there even a surface to reflect off after second shock?
- How do you quantify ejecta in spectrograms?

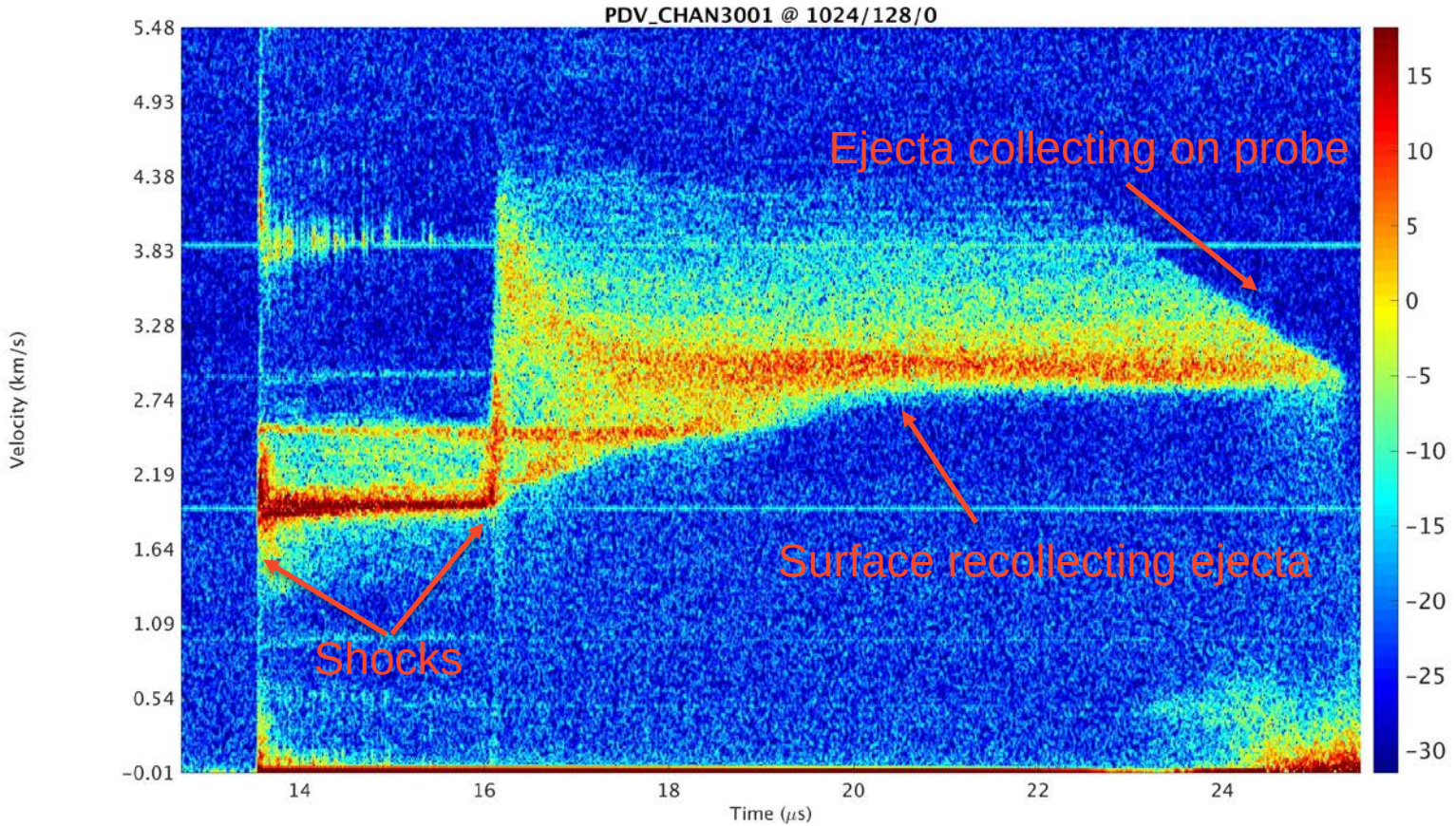
- Will use Silverleaf series to motivate answers

Silverleaf

- **Series of 4 shots done at LANL in Summer 2016**
- **Double-shock drives on tin**
  - Lots of ejecta
- **Fielded:**
  - Prototype Gen-1 mPDV
    - 16 channels
    - Mostly for Asay foils
  - Gen-3 PDV
    - 32 channels
  - Vanilla PDV
    - 4 channels
    - 1.25W/channel
  - BLR
    - 2 channels
    - On same probes as 2 Gen-3 channels



Spectrogram from Silverleaf



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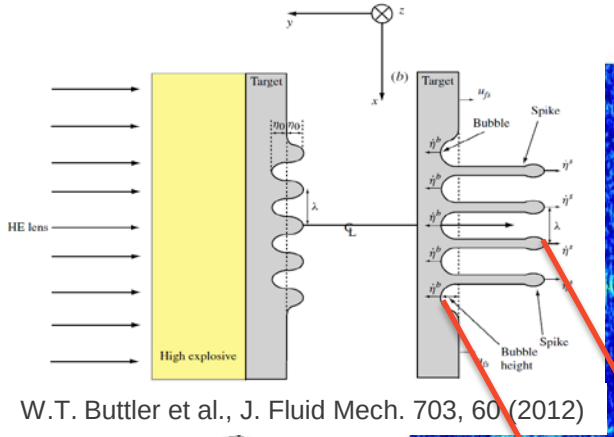


W.T. Buttler et al., J. Fluid Mech. 703, 60 (2012)

PDV_CHAN3001 @ 1024/128/0

Ejecta collecting on probe

Surface recollecting ejecta

Shocks

Velocity (

2.74
2.19
1.64
1.09
0.54
-0.01

14 16 18 20 22 24

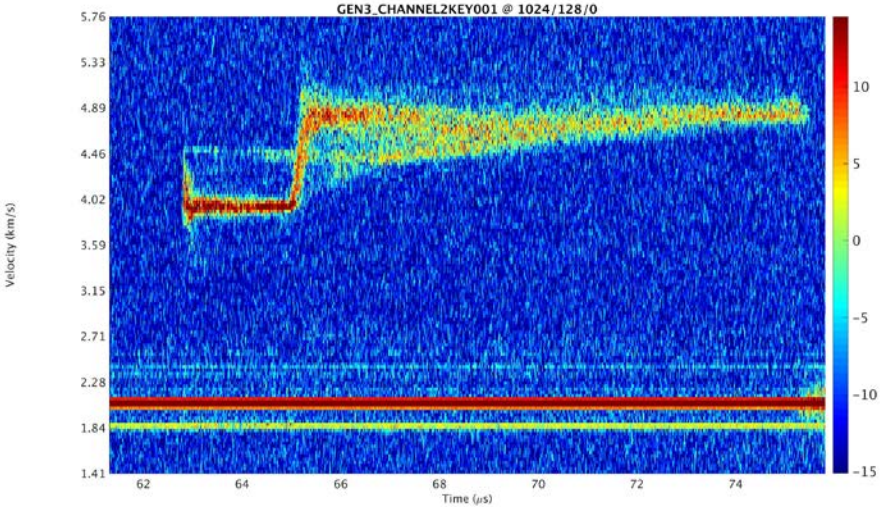
Time (μs)

15 10 5 0 -5 -10 -15 -20 -25 -30

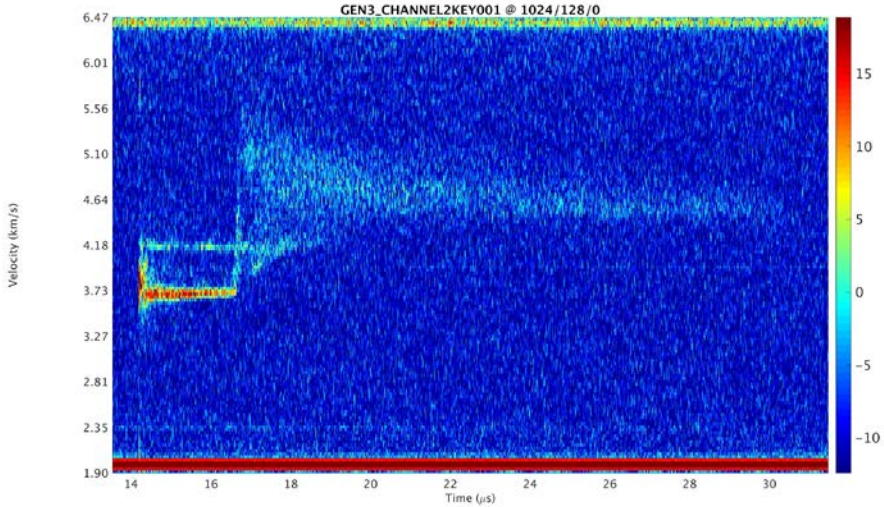
Silverleaf Lesson 1 – Focused Probes are Bad for Ejecta

- **Tried one focused probe on Silverleaf C and D**
  - Focused just above the surface
  - Gave similar S/N as collimated probe at first shock
  - During ejecta (over large distance) collimated probe had much better S/N

Gen-3 Collimated



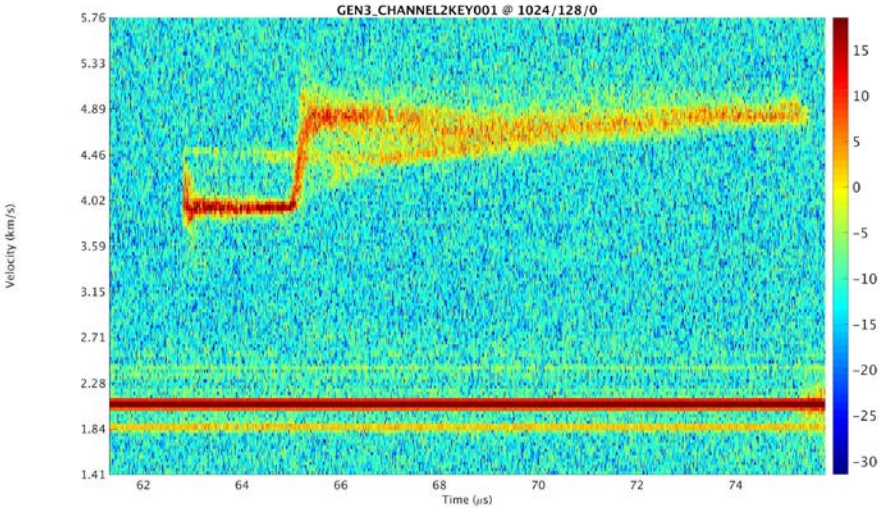
Gen-3 Focused



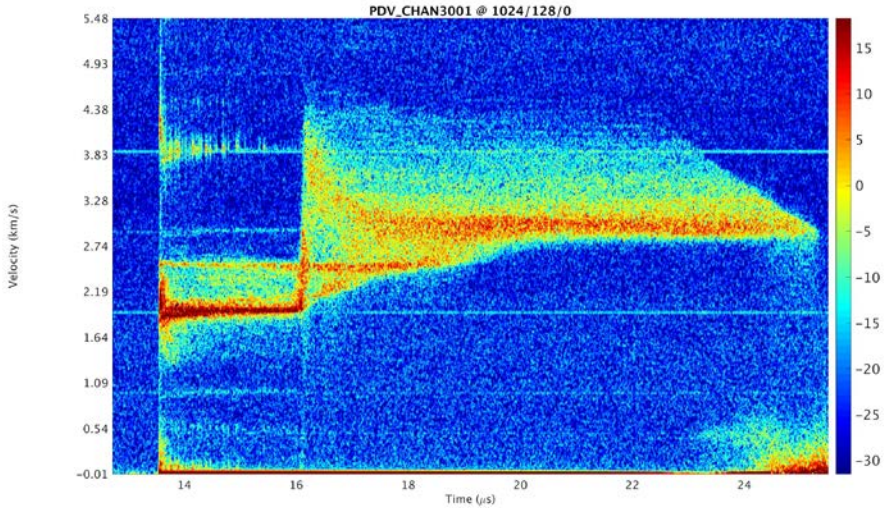
Silverleaf Lesson 2 – High power PDV Helps Understanding

- 4 Vanilla PDV at 1.25W/channel
- >10dB better S/N than Gen-3
- Features stand out much better
- Makes interpretations of Gen-3 spectrograms more robust

Gen-3 mPDV



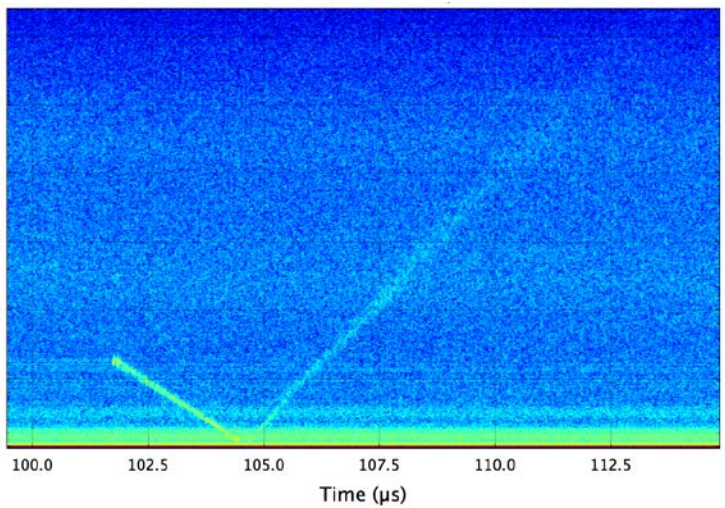
Vanilla PDV



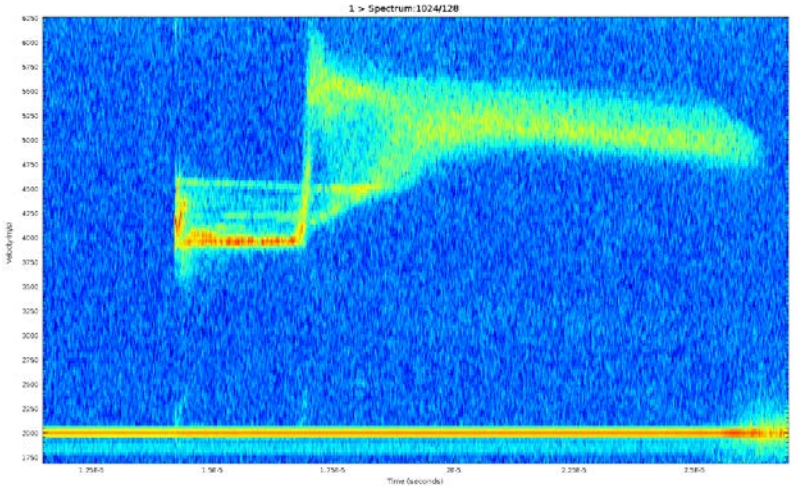
Silverleaf Lesson 3 – BLR May Help with Ejecta

- 2 BLR add/dropped onto Gen-3 mPDV probes
- Shows spatial coincidence of different-velocity surfaces
- Shows spatial separation of similar-velocity surfaces

BLR



Gen-3 mPDV



Nightshade Need 1: Time-Duplexed Vanilla PDV

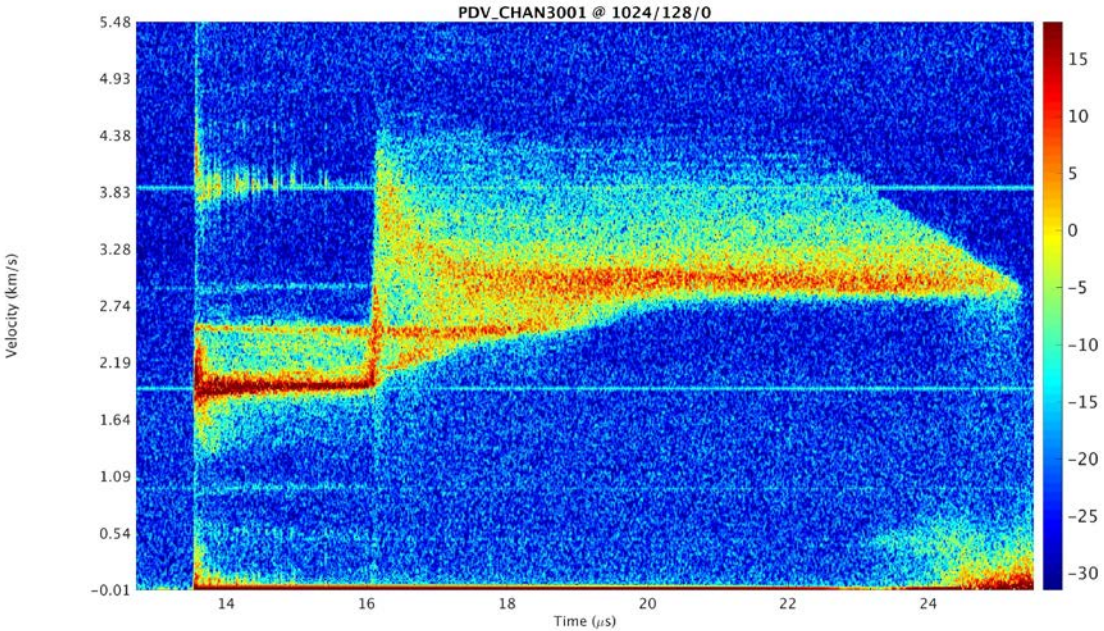
- **Vanilla PDV has better S/N than Gen-3 mPDV**
  - Even at comparable power
- **Design a time-duplexed Vanilla PDV system**
  - To limit the number of oscilloscopes needed to run many Vanilla PDV channels
  - Even 2 deep in time should be enough to limit oscilloscope usage
  - Plan to use nanospeed switches, tens of microseconds delay is time between channels
    - To minimize cross-talk between channels

Nightshade Need 2: High Power PDV System

- **Cannot use Watt-level PDV systems over long distances**
  - SBS kills power
  - Also cannot use MT connectors
- **Develop system broken into two parts**
  - Laser, circulators in room with package
  - Output of circulators is output of first chassis
  - Local oscillator, delays, nanospeed switches, photo detectors, oscilloscopes in second chassis hundreds of feet away
- **At least 1 point on each target to give strong reference spectrogram for other probes**

Nightshade Idea 3: How to Analyze Ejecta

- **Cannot just give velocity-vs-time**
- **More details needed**
  - Shape
  - Width
  - Density of signal
  - Multiple signals at one time
- **Working with end-users on how to best present the data**
- **Working with Abel Diaz (MSTS) on how to extract**
- **Ideas?**
  - Franzkowiak et al., Review of Shock Instruments 89, 033901 (2018) ?



Conclusions

- **Nightshade should push the PDV systems and analysis to the limits**
  - That’s how progress gets made
- **If anyone has refinements/criticisms/ideas of how to best accomplish these measurements and analyses, please let me know**
  - All ideas are welcome